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## TROPICAL DEFORESTATION

by Rebecca Lindsey • design by Robert Simmon • March 30, 2007



Stretching out from the equator on all Earth's land surfaces is a wide belt of forests of amazing diversity and productivity. Tropical forests include dense rainforests, where rainfall is abundant year-round; seasonally moist forests, where rainfall is abundant, but seasonal; and drier, more open woodlands. Tropical forests of all varieties are disappearing rapidly as humans clear the natural landscape to make room for farms and pastures, to harvest timber for construction and fuel, and to build roads and urban areas. Although deforestation meets some human needs, it also has profound, sometimes devastating, consequences, including social conflict, extinction of plants and animals, and climate change—challenges that aren't just local, but global. NASA supports and conducts research on tropical forests from space-based and ground-based perspectives, helping provide the information that national and international leaders need to develop strategies for sustaining human populations and preserving tropical forest biodiversity.

(Photograph courtesy U. S. Forest Service.)

The [original version](#) of this fact sheet, by Gerald Urquhart, Walter Chomentowski, David Skole, and Chris Barber, and published in 1999, is archived as a PDF.

### Tropical Deforestation

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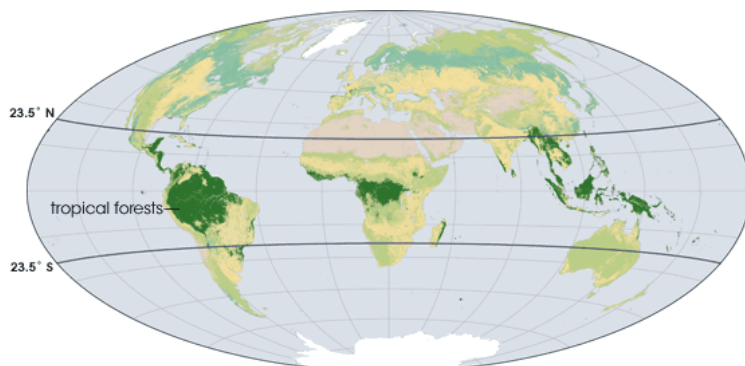
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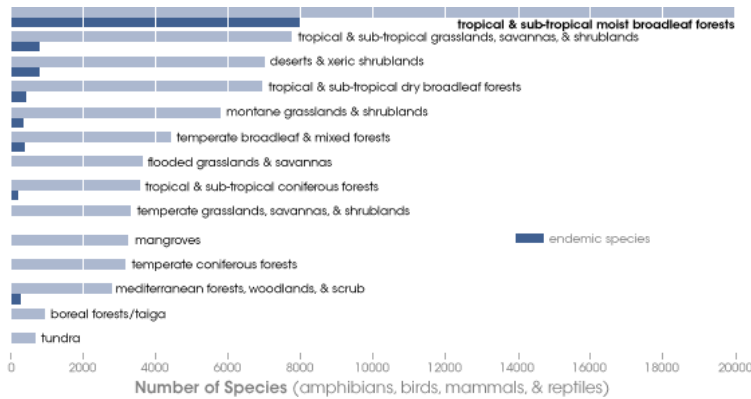
### Impacts of Deforestation: Biodiversity Impacts

Although tropical forests cover only about 7 percent of the Earth's dry land, they probably harbor about half of all species on Earth. Many species are so specialized to microhabitats within the forest that they can only be

Tropical forests span both sides of the Equator, thriving in the warm, usually wet, climate, under the Sun's most direct rays. Evergreen forests between the Tropic of Cancer (North) and Tropic of

found in small areas. Their specialization makes them vulnerable to extinction. In addition to the species lost when an area is totally deforested, the plants and animals in the fragments of forest that remain also become increasingly vulnerable, sometimes even committed, to extinction. The edges of the fragments dry out and are buffeted by hot winds; mature rainforest trees often die standing at the margins. Cascading changes in the types of trees, plants, and insects that can survive in the fragments rapidly reduces biodiversity in the forest that remains. People may disagree about whether the extinction of other species through human action is an ethical issue, but there is little doubt about the practical problems that extinction poses.

Capricorn (South) are dark green on this map, while other biomes are lighter. (Image by Robert Simmon, based on Moderate Resolution Imaging Spectroradiometer [Land Cover Classification](#) data.)



First, global markets consume rainforest products that depend on sustainable harvesting: latex, cork, fruit, nuts, timber, fibers, spices, natural oils and resins, and medicines. In addition, the genetic diversity of tropical forests is basically the deepest end of the planetary gene pool. Hidden in the genes of plants, animals, fungi, and bacteria that have not even been discovered yet may be cures for cancer and other diseases or the key to improving the yield and nutritional quality of foods—which the U.N. Food and Agriculture Organization says will be crucial for feeding the nearly ten billion people the Earth will likely need to support in coming decades. Finally, genetic diversity in the planetary gene pool is crucial for the resilience of all life on Earth to rare but catastrophic environmental events, such as meteor impacts or massive, sustained volcanism.

#### Soil Impacts

With all the lushness and productivity that exist in tropical forests, it can be surprising to learn that tropical soils are actually very thin and poor in nutrients. The underlying “parent” rock weathers rapidly in the tropics’ high temperatures and heavy rains, and over time, most of the minerals have washed from the soil. Nearly all the nutrient content of a tropical forest is in the living plants and the decomposing litter on the forest floor.

Tropical forests contain more species than any other ecosystem, as well as a higher proportion of endemic (unique) species. As people clear large areas of tropical forests, entire species are vanishing, many of them unknown. (Graph adapted by Robert Simmon from the [Millennium Ecosystem Assessment](#) *Biodiversity Synthesis*.)

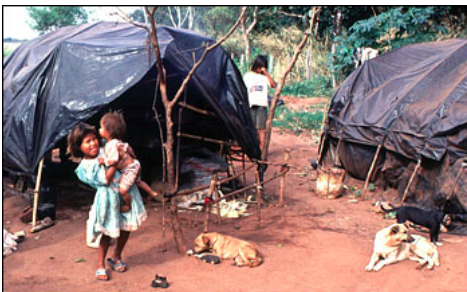


When an area is completely deforested for farming, the farmer typically burns the trees and vegetation to create a fertilizing layer of ash. After this slash-and-burn deforestation, the nutrient reservoir is lost, flooding and erosion rates are high, and soils often become unable to support crops in just a few years. If the area is then turned into cattle pasture, the ground may become compacted as well, slowing down or preventing forest recovery.

#### Social Impacts

Tropical forests are home to millions of native (indigenous) people who make their livings through subsistence agriculture, hunting and gathering, or through low-impact harvesting of forest products like rubber or nuts. Deforestation in indigenous territories by loggers, colonizers, and refugees has sometimes triggered violent conflict. Forest preservation can be socially divisive, as well. National and international governments and aid agencies struggle with questions about what level of human presence, if any, is compatible with conservation goals in tropical forests, how to balance the needs of indigenous peoples with expanding rural populations and national economic development, and whether establishing large, pristine, uninhabited protected areas—even if that means removing current residents—should be the highest priority of conservation efforts in tropical forests.

The organic material and nutrients in a tropical rainforest are found in the vegetation itself, not in the soil. This eroded hillside along a river in Amazonia shows the infertile soil typical of tropical environments (pinkish-tan) topped by a very thin layer of fertile soil and forest detritus (brown). (Photograph ©2007 Guenter Fischer and [World of Stock](#).)



Logging, mining, and farming in tropical forests sometimes displace indigenous communities. Left without land or other resources, native cultures often disintegrate. This displaced group of Guarani Indians lives in a makeshift camp along the road in Mato Grosso do Sul, Brazil. (Photograph ©2001 [nagillum](#).)

#### ► Climate Impacts

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#### Tropical Deforestation

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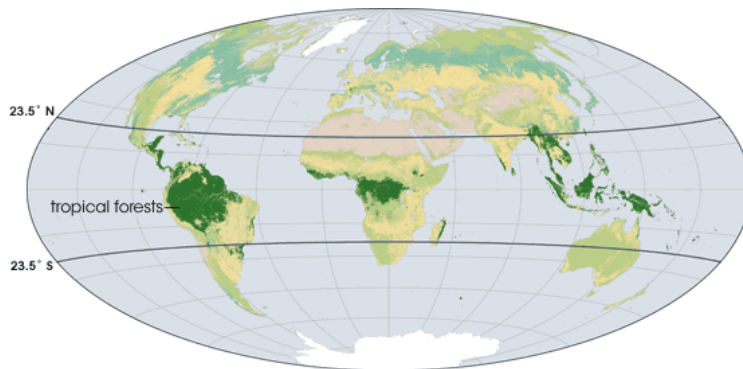
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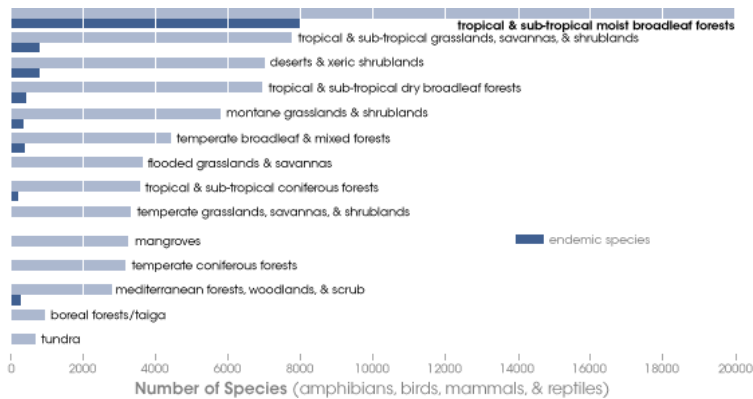


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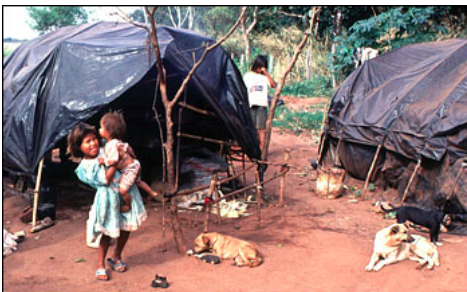


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#### ► Climate Impacts

##### Climate Impacts: Rainfall and Temperature

Up to thirty percent of the rain that falls in tropical forests is water that the rainforest has recycled into the

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atmosphere. Water evaporates from the soil and vegetation, condenses into clouds, and falls again as rain in a perpetual self-watering cycle. In addition to maintaining tropical rainfall, the evaporation cools the Earth's surface. In many computer models of future climate, replacing tropical forests with a landscape of pasture and crops creates a drier, hotter climate in the tropics. Some models also predict that tropical deforestation will disrupt rainfall pattern far outside the tropics, including China, northern Mexico, and the south-central United States.

Most of these climate predictions of decreased rainfall are based on a uniform and virtually complete replacement of tropical forests with pasture and cropland. However, deforestation often proceeds in a patchwork fashion—clearings that branch off roads in a fishbone pattern, for example, or deforested islands within a sea of forest. On these local scales, deforestation may actually increase rainfall by creating “heat islands” that enhance the rising and overturning of air (convection) that leads to clouds and rain. Clouds and rainfall becomes concentrated over clearings. Whether the localized enhancement of rainfall will persist as larger and larger areas of forest are cleared is not currently known. Answers may come from more sophisticated climate models that accurately represent the patchwork progression of partially deforested landscapes.

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### The Carbon Cycle and Global Warming

In the Amazon alone, scientists estimate that the trees contain more carbon than 10 years worth of human-produced greenhouse gases. When people clear the forests, usually with fire, carbon stored in the wood returns to the atmosphere, enhancing the greenhouse effect and global warming. Once the forest is cleared for crop or grazing land, the soils can become a large source of carbon emissions, depending on how farmers and ranchers manage the land. In places such as Indonesia, the soils of swampy lowland forests are rich in partially decayed organic matter, known as peat. During extended droughts, such as during El Niño events, the forests and the peat become [flammable](#), especially if they have been degraded by logging or accidental fire. When they burn, they release huge volumes of carbon dioxide and other greenhouse gases.

Deforestation changes local weather. Cloudiness and rainfall can be greater over cleared land (image right) than over intact forest (left). This image of Alta Floresta, Brazil, was captured by the Moderate Resolution Imaging Spectroradiometer (MODIS) aboard NASA's Aqua satellite on August 29, 2006. (NASA image by Robert Simmon and Jesse Allen, based on data from the [MODIS](#) science team.)





It is not certain whether intact tropical forests are a net source or sink of carbon. Certainly, the trunks of trees are a large, stable pool of carbon that grows as forests mature or regenerate on previously cleared land. But trees, plants, and microorganisms in the soil also respire, releasing carbon dioxide as they break down carbohydrates for energy. In the Amazon, huge volumes of carbon dioxide [escape](#) from decaying leaves and other organic matter in rivers and streams that flood large areas of forest during the rainy season. Undisturbed tropical forests may be nearly neutral with respect to carbon, but deforestation and degradation are currently a source of carbon to the atmosphere and have the potential to turn the tropics into an even greater source in coming decades.

Wildfires and slash and burn agriculture release carbon dioxide that would otherwise be stored in the forest biomass into the atmosphere. Forest regrowth and crops recapture some carbon, but overall, deforestation is a source of atmospheric carbon dioxide and therefore a contributor to global warming. (Photograph ©2007 [mke1963](#).)

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#### Causes of Deforestation: Direct Causes

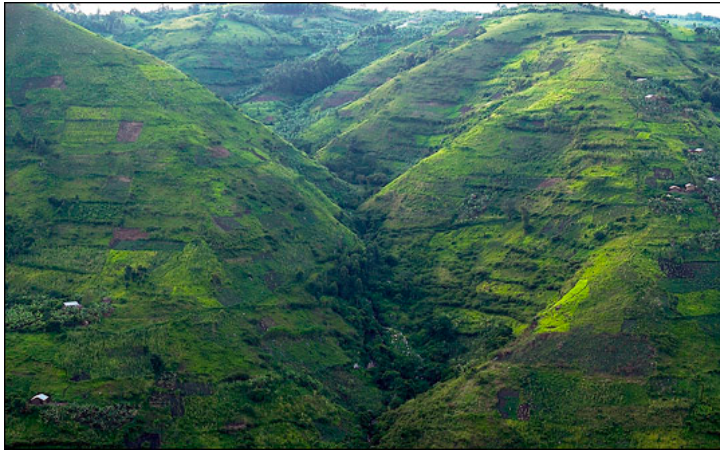
People have been deforesting the Earth for thousands of years, primarily to clear land for crops or livestock. Although tropical forests are largely confined to developing countries, they aren't just meeting local or national needs; economic globalization means that the needs and wants of the global population are bearing down on them as well. Direct causes of deforestation are agricultural expansion, wood extraction (e.g., logging or wood harvest for domestic fuel or charcoal), and infrastructure expansion such as road building and urbanization. Rarely is there a single direct cause for deforestation. Most often, multiple processes work simultaneously or sequentially to cause deforestation.

The single biggest direct cause of tropical deforestation is conversion to cropland and pasture, mostly for subsistence, which is growing crops or raising livestock to meet daily needs. The conversion to agricultural land usually results from multiple direct factors. For example, countries build roads into remote areas to improve overland transportation of goods. The road development itself causes a limited amount of deforestation. But roads also provide entry to previously inaccessible—and often unclaimed—land. Logging, both legal and illegal, often follows road expansion (and in some cases is the reason for the road expansion). When loggers have harvested an area's valuable timber, they move on. The roads and the logged areas become a magnet for settlers—farmers and ranchers who [slash and burn](#) the remaining forest for cropland or cattle pasture, completing the deforestation chain that began

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with road building. In other cases, forests that have been degraded by logging become fire-prone and are eventually deforested by repeated accidental fires from adjacent farms or pastures.



Although subsistence activities have dominated agriculture-driven deforestation in the tropics to date, large-scale commercial activities are playing an increasingly significant role. In the Amazon, industrial-scale cattle ranching and soybean production for world markets are increasingly important causes of deforestation, and in Indonesia, the conversion of tropical forest to commercial palm tree plantations to produce bio-fuels for export is a major cause of deforestation on Borneo and Sumatra.

In densely populated central Africa, small subsistence plots cover the once-forested hillsides. (Photograph ©2006 Stefan Gara.)



#### Underlying Causes

Although poverty is often cited as *the* underlying cause of tropical deforestation, analyses of multiple scientific studies indicate that that explanation is an oversimplification. Poverty does drive people to migrate to forest frontiers, where they engage in slash and burn forest clearing for subsistence. But rarely does one factor alone bear the sole responsibility for tropical deforestation.

State policies to encourage economic development, such as road and railway expansion projects, have caused significant, unintentional deforestation in the Amazon and Central America. Agricultural subsidies and tax breaks, as well as timber concessions, have encouraged forest clearing as well. Global economic factors such as a

On the southern margin of the Amazon, in the state of Mato Grosso, Brazil, huge expanses of rainforest are being cleared by industrial soybean, sugar cane, and maize producers. (Photograph ©2006 Guido van der Werf, Vrije Universiteit, Amsterdam.)

country's foreign debt, expanding global markets for rainforest timber and pulpwood, or low domestic costs of land, labor, and fuel can encourage deforestation over more sustainable land use.



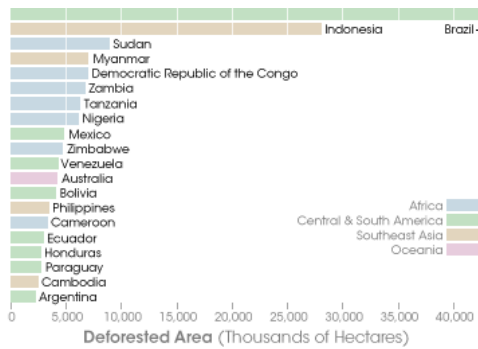
Access to technology may either enhance or diminish deforestation. The availability of technologies that allow "industrial-scale" agriculture can spur rapid forest clearing, while inefficient technology in the logging industry increases collateral damage in surrounding forests, making subsequent deforestation more likely. Underlying factors are rarely isolated; instead, multiple global and local factors exert synergistic influences on tropical deforestation in different geographic locations.

In addition to local factors, international trends drive deforestation. The expansion of palm oil plantations in Indonesia and Malaysia is a response to high petroleum prices and, ironically, to an increasing global demand for bio-fuels perceived to be "green." (Photograph ©2006 Badly Drawn Dad.)

#### **Rates of Tropical Deforestation**

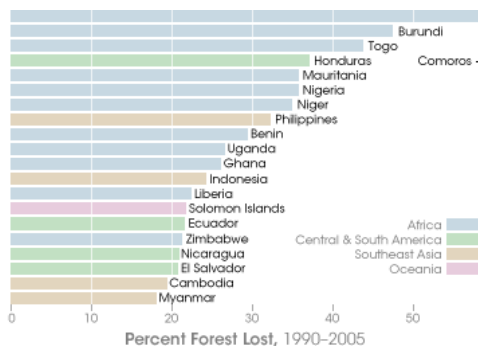
Several international groups produce routine estimates of tropical deforestation, most notably the Food and Agriculture Organization (FAO) of the United Nations, which has been producing a global forest resources assessment every five to ten years since the late 1940s. The FAO report is based on statistics provided by countries themselves, and because the ability of countries to accurately assess their forest resources varies depending on their financial, technological, and institutional resources, the estimates for some countries are likely more accurate than others. Many countries use satellite imagery as the basis for their assessments, and a few research teams have used satellite data as the basis for worldwide estimates of tropical deforestation in the 1980s and 1990s.

Some scientists and conservationists argue that the FAO provides too conservative an estimate of rates of deforestation because they consider any area larger than one hectare (0.01 square miles) with a minimum tree cover of 10 percent to be forested. This generous definition of "forest" means that a significant amount of degradation can occur before the FAO categorizes an area as deforested. On the other hand, some satellite-based studies indicate deforestation rates are lower than even the FAO reports suggest. In the FAO's most recent forest assessment report, published in 2005, the organization itself revised downward the deforestation rates for the 1990s that it reported in 2001. Despite revisions and discrepancies, the FAO assessment is the most comprehensive, longest-term, and widely used metric of global forest resources.



All tropical forest sub-regions (coded by color) are represented in a list of the top 20 countries that cleared the most forest between 1990 and 2005. Brazil, the leader, cleared over 42 million hectares, an area the size of California. (Graphic by Robert Simmon, based on data provided by individual countries to the U.N. Foreign Agricultural Organization for the [Global Forest Resources Assessment Report 2005](#).)

The FAO report does not compile statistics for tropical forest regions as a whole, but the country-by-country and regional-scale statistics provide a grim picture. The scope and impact of deforestation can be viewed in different ways. One is in absolute numbers: total area of forest cleared over a certain period. By that metric, all three major tropical forest areas, including South America, Africa, and Southeast Asia, are represented near the top of the list. Brazil led the world in terms of total deforested area between 1990 and 2005. The country lost 42,330,000 hectares (163,436 square miles) of forest, roughly the size of California. Rounding out the top five tropical countries with the greatest total area of deforestation were Indonesia, Sudan, Myanmar, and the Democratic Republic of Congo.



Although all major tropical forest sub-regions (coded by color) are represented in a list of the top 20 countries that cleared the largest percentage of their forests between 1990 and 2005, African countries (blue bars) dominate, beginning with Comoros, a small island nation north of Madagascar. (Graphic by Robert Simmon, based on data provided by individual countries to the U.N. Foreign Agricultural Organization for the [Global Forest Resources Assessment Report 2005](#).)

Another way to look at deforestation is in terms of the percent of a country's forest that was cleared over time. By this metric, the island nation of Comoros (north of Madagascar) fared the worst, clearing nearly 60 percent of its forests between 1990 and 2005. Landlocked Burundi in central Africa was second, clearing 47 percent of its forests. The other top five countries that cleared large percentages of their forests were Togo, in West Africa (44 percent); Honduras (37 percent); and Mauritania (36 percent). Thirteen other tropical countries or island territories cleared 20 percent or more of their forests between 1990-2005.

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#### NASA Tropical Deforestation Research

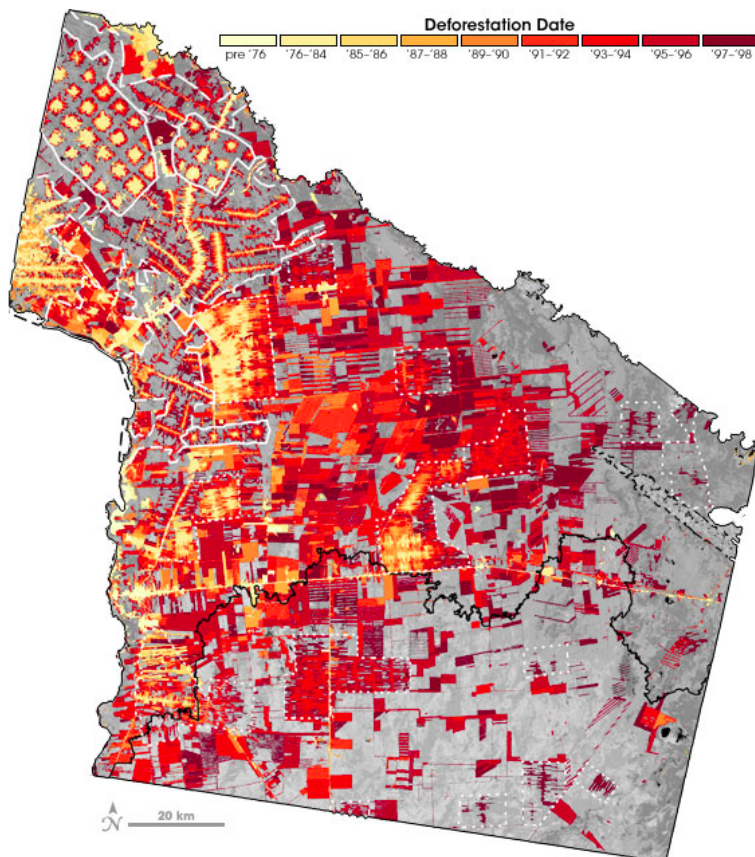
NASA remote-sensing technology has become the backbone of worldwide efforts to quickly, routinely, and reliably assess trends in tropical deforestation. Since the 1970s, the [Landsat](#) series of satellites has provided high-resolution imagery (resolution means "level of detail") of changes in tropical forests over time. The most comprehensive use of Landsat data to map tropical

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deforestation has been NASA's [Landsat Pathfinder Humid Tropical Deforestation Project](#), a collaborative effort among scientists from the University of Maryland, the University of New Hampshire, and NASA's Goddard Space Flight Center. The project yielded deforestation maps for the Amazon Basin, Central Africa, and Southeast Asia for three periods in the 1970s, 1980s, and 1990s.

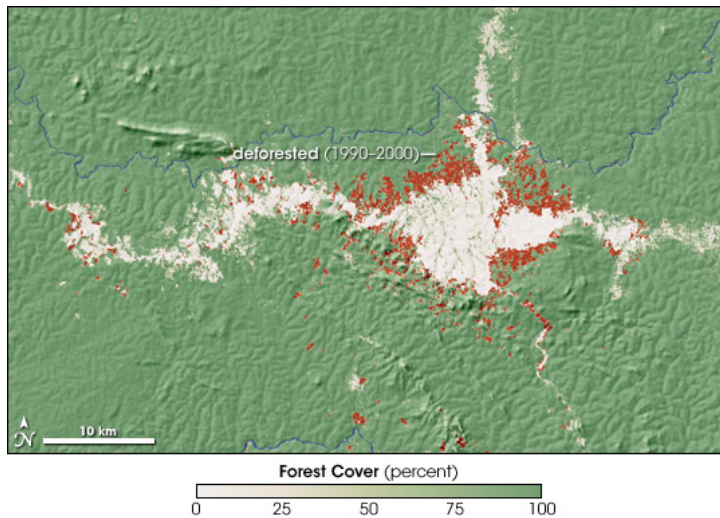
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Agencies and scientists across the globe continue to use Landsat data to monitor deforestation and to enforce environmental policies. For example, in 2003, the state of Mato Grosso, Brazil, piloted a successful timber licensing system in which property maps were combined with Landsat images to routinely document and issue fines for clearing that exceeded legally licensed limits. As part of a USAID (United States Agency for International Development) initiative called the [Central African Regional Program for the Environment](#), scientists are drawing on experience from the Pathfinder project to improve methods for detecting deforestation and degradation in the Congo Basin. The initiative is producing new decadal forest change maps using Landsat data from the 1990s through 2005.

Scientists use data from the Landsat series of satellites, which date back to 1972, to make detailed maps of deforestation over time. With resolutions up to 15 meters per pixel, the data reveal cleared areas as small as an office building. This [map](#) shows the progress of deforestation in Tierras Bajas, Bolivia. Areas deforested before 1976 are pale yellow, while areas cleared from 1997-98 are dark red. (NASA map by Marc Steiner.)





High-resolution sensors such as Landsat, [ASTER](#) (Advanced Spaceborne Thermal Emission and Reflection Radiometer) and [ALI](#) (the Advanced Land Imager) provide a detailed picture of deforestation, but the detail comes at a price. The greater the surface detail a sensor can observe, the smaller the area it can view in a single image. This tradeoff between detail and coverage makes high-resolution sensors less suitable for routine deforestation mapping on a global scale. In addition to the problem of spatial coverage, high-resolution data generates large data files that require significant computer and internet resources to analyze, to combine into regional or global-scale maps, and to distribute to scientists and agencies that need them.

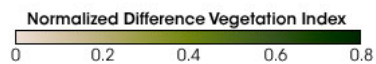
This map shows percent forest cover in eastern Democratic Republic of the Congo. Red areas, expanding outward from the town of Mambasa, show deforestation between 1990 and 2000. (Map by Robert Simmon, based on data from the [Decadal Forest Change Mapping Project](#).)



September 9, 2000

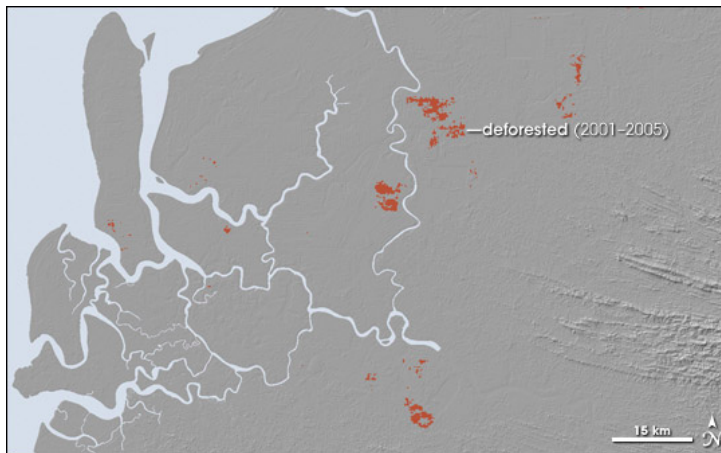


September 26, 2006



Today, the [MODIS](#) sensors (short for Moderate Resolution Imaging Spectroradiometer) on NASA's Terra and Aqua satellites provide a compromise between level of detail and spatial coverage. The two sensors observe almost the entire Earth each day, providing a daily portrait of tropical forests at a spatial resolution of 250 meters per image pixel. Scientists at the University of Maryland have used MODIS data to develop an annual set of images showing where human-caused change in vegetation—including deforestation and burning—have occurred in the previous year. The team refers to the product as an “alarm” product, which can draw researchers’ or natural resource managers’ attention to areas undergoing rapid change. By combining the large-scale coverage of the MODIS change-detection “alarm” maps with the more detailed Landsat and ASTER images, scientists are developing automated forest-monitoring systems that can rapidly detect tropical deforestation.

Some areas of Rondonia, Brazil, have been almost completely deforested in just 6 years. This pair of images uses a scale, or index, of vegetation to compare forest area in 2000 to 2006 at the full resolution (15 meters per pixel) of the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) instrument. Cleared areas (tan) spread from roads cut through the forest (green), a pattern of deforestation typical in Rondonia. (Maps by Robert Simmon, based on [ASTER](#) data.)



NASA also pioneers the development and testing of new technologies for observing tropical forests, including hyperspectral sensors that observe more than 200 wavelengths of light reflected from the Earth and active sensors such as lidars, which probe the different layers of dense forests with pulses of laser light. In addition to the development of remote sensors and the collection, processing, and distribution of the data they collect, NASA also funds national and international research into the causes and consequences of deforestation. NASA (and NASA-funded) scientists develop predictive models, analyze satellite data for deforestation trends, and lead ground-based research that complements space-based observations.

The coastal lowlands of Borneo are another region where deforestation is widespread, often for palm tree plantations. Satellite sensors with a resolution of several hundred meters per pixel, such as MODIS, give a broad overview of deforestation. Frequent observations can sound an alarm to scientists about where rapid land cover change is happening. (Map by Robert Simmon, based on MODIS [Vegetation Cover Conversion](#) data.)

Among the agency's most important efforts is its participation in the Large-Scale Biosphere-Atmosphere Experiment in Amazonia ([LBA](#)). Led by Brazil, the experiment is an international research initiative to understand the Amazon ecosystem, how deforestation and climate change will affect the ecosystem's functioning, and how the Amazon interacts with the larger Earth system. Under the umbrella of LBA, NASA-funded scientists have refined estimates of the extent of deforestation; developed new ways to identify degraded-but-not-yet-deforested areas; demonstrated the impacts of logging, road-building, El Niño, and fire on tropical forests; and discovered that the seasonally flooded parts of the forests are a major source of atmospheric carbon dioxide.

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#### Sustaining Tropical Forests

Strategies for preserving tropical forests can operate on local to international scales. On a local scale, governments and non-governmental organizations are working with forest communities to encourage low-impact agricultural activities, such as shade farming, as well as the sustainable harvesting of non-wood forest products such as rubber, cork, produce, or medicinal plants. Parks and protected areas that draw tourists—ecotourism—can provide employment and educational opportunities for local people as well as creating or stimulating related service-sector economies.

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On the national scale, tropical countries must integrate existing research on human impacts on tropical ecosystems into national land use and economic development plans. For tropical forests to survive, governments must develop realistic scenarios for future deforestation that take into account what scientists already know about the causes and consequences of deforestation, including the unintended deforestation that results from road-building, accidental fire, selective logging, and economic development incentives such as timber concessions and agricultural subsidies.

Although deforestation in the tropics is rapid and widespread, some people are making an increasing effort to mitigate potential disaster. Sustainable harvesting of native plants, shade farming, nature preserves, and management by indigenous peoples are techniques that help maintain a vital resource. (Photograph ©2006 [Leo F. Freitas](#).)



Several scientists are encouraging the conservation community to re-consider the belief that vast, pristine parks and protected areas are the holy grail of forest conservation. In 2005, for example, scientists using satellite and ground-based data in the Amazon demonstrated that far less “unfettered” deforestation occurred in recent decades within territories occupied and managed by indigenous people than occurred in parks and other protected areas. The year before, scientists studying Indonesia’s tropical forests documented a 56 percent decline in tropical lowland forests in protected areas of Borneo between 1985 and 2001. They concluded that the deforestation in the protected areas resulted from a combination of illegal logging and devastating fires that raged through logging-damaged forests during the 1997-1998 El Niño-triggered drought. While some might argue that these losses could be prevented in the future through better enforcement of environmental laws, it may also

Shade-grown coffee and other types of farming that preserve mature trees are ways to maintain much of the biodiversity and ecosystem functions of the tropical forest while providing jobs and sustaining economic development. (Photograph ©2006 [Michael Bollino](#).)



be true that inhabited forest reserves are a more realistic strategy for preserving the majority of biodiversity in larger areas than parks alone can accomplish.

Finally, on the national and international scale, an increasing value in the global marketplace for products that are certified as sustainably produced or harvested—timber, beef, coffee, soy—may provide incentives for landowners to adopt more forest-friendly practices, and for regional and national governments to create and enforce forest-preservation policies. Direct payments to tropical countries for the ecosystem services that intact tropical forest provide, particularly for carbon storage to offset greenhouse gas emissions, are likely to become an important international mechanism for sustaining tropical forests as more countries begin to seriously tackle the problem of global warming.

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